



**California Energy Commission
Overview of PIER Contract No.
500-98-028**

*Design Refinement and
Demonstration of Heat Pump
Water Heater*

**Residential Heat Pump
Water Heater Technology
and Markets:**

*Progress since Atlanta and
Prospects for 2003*

**December 4-5, 2002
Portland, Oregon**

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Reference 75862

The Market-Optimized HPWH¹ addresses the cost and installation barriers associated with previous HPWHs, as demonstrated by ECR's Watter\$aver.



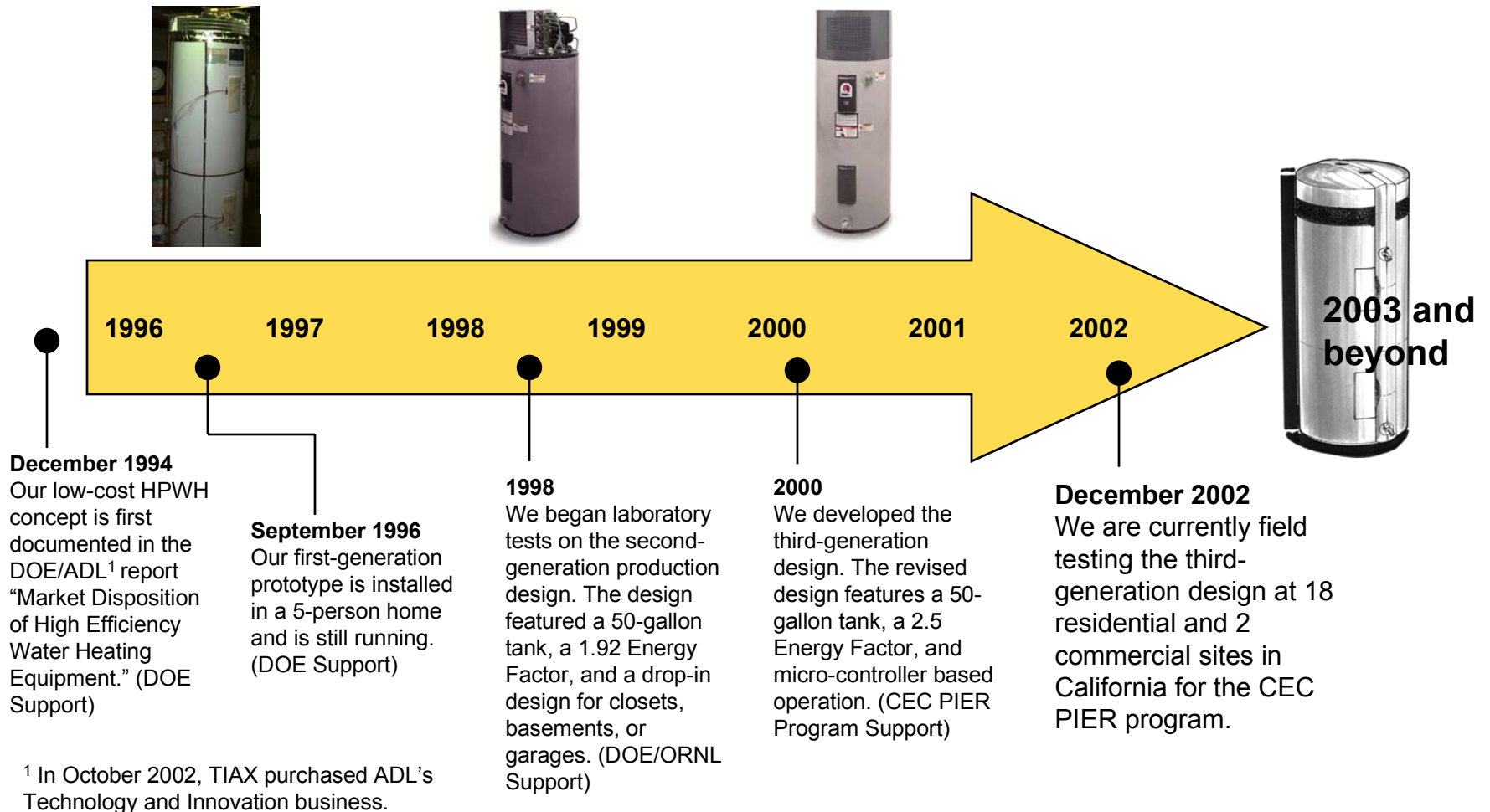
Key Features

- Uses 40 to 60% less electricity than electric-resistance (EF = 2.4)
- Costs significantly less than current HPWH designs in volume production
- Backup electric-resistance elements ensure performance at all times
- The drop-in design allows easy installation just like a conventional electric water heater - no condensate drain² or ventilation is required
- Micro-controller based operation

1. U.S. Patents 5,906,109, 5,946,927, 6,199,395, and 6,257,002 apply

2. With drain-free option package (The ECR Watter\$aver product uses an optional electric-resistance element in the drain pan)

With support from the DOE and the CEC PIER Program, and in partnership with ECR and ORNL, TIAX has been developing and testing a market-optimized HPWH since 1996.

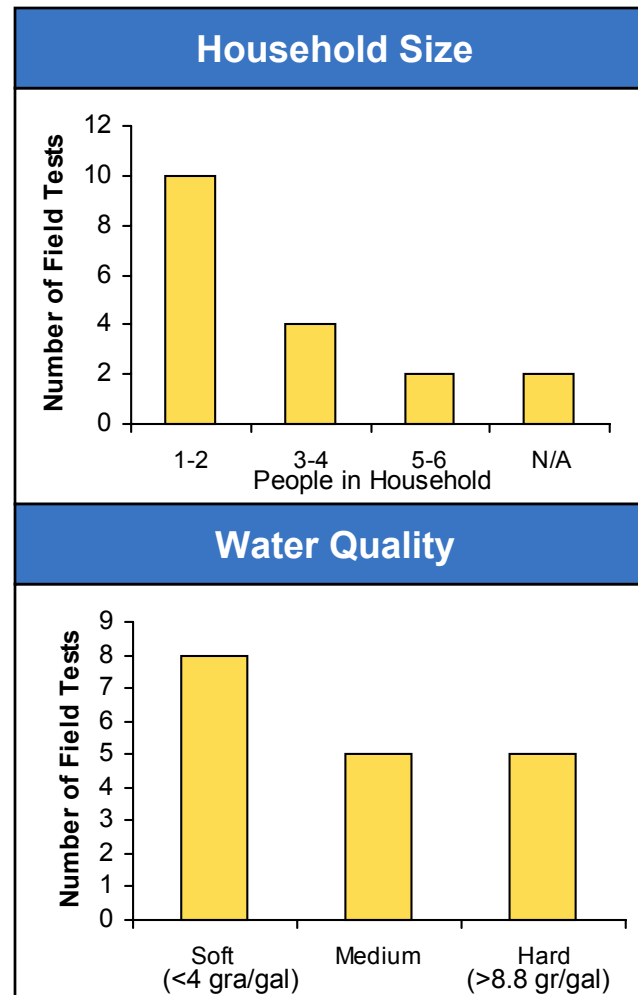
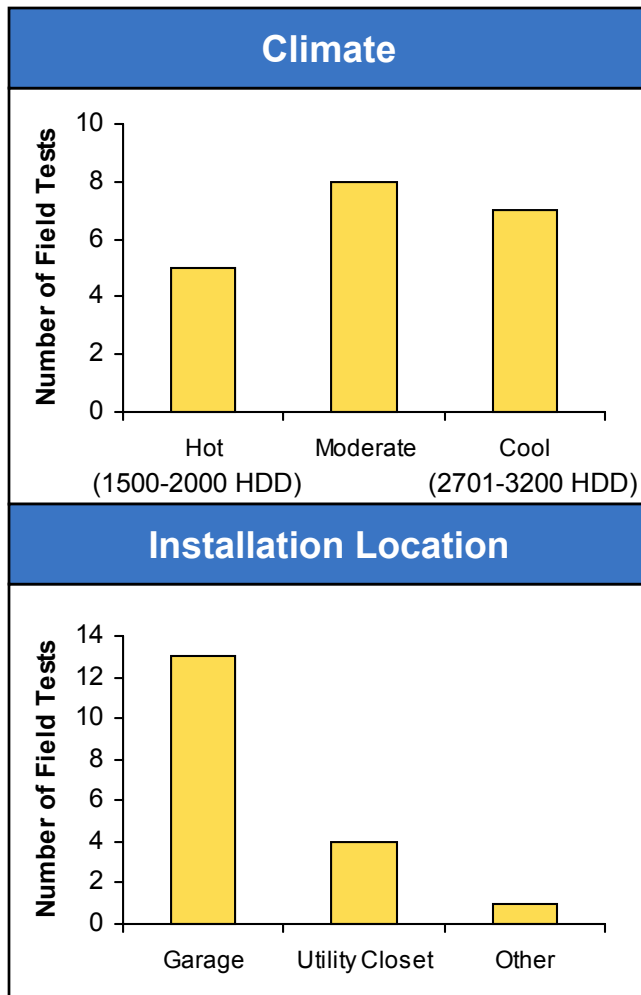


¹ In October 2002, TIAX purchased ADL's Technology and Innovation business.

The CEC PIER project includes design refinements and field testing of the Market-Optimized HPWH as manufactured by ECR.

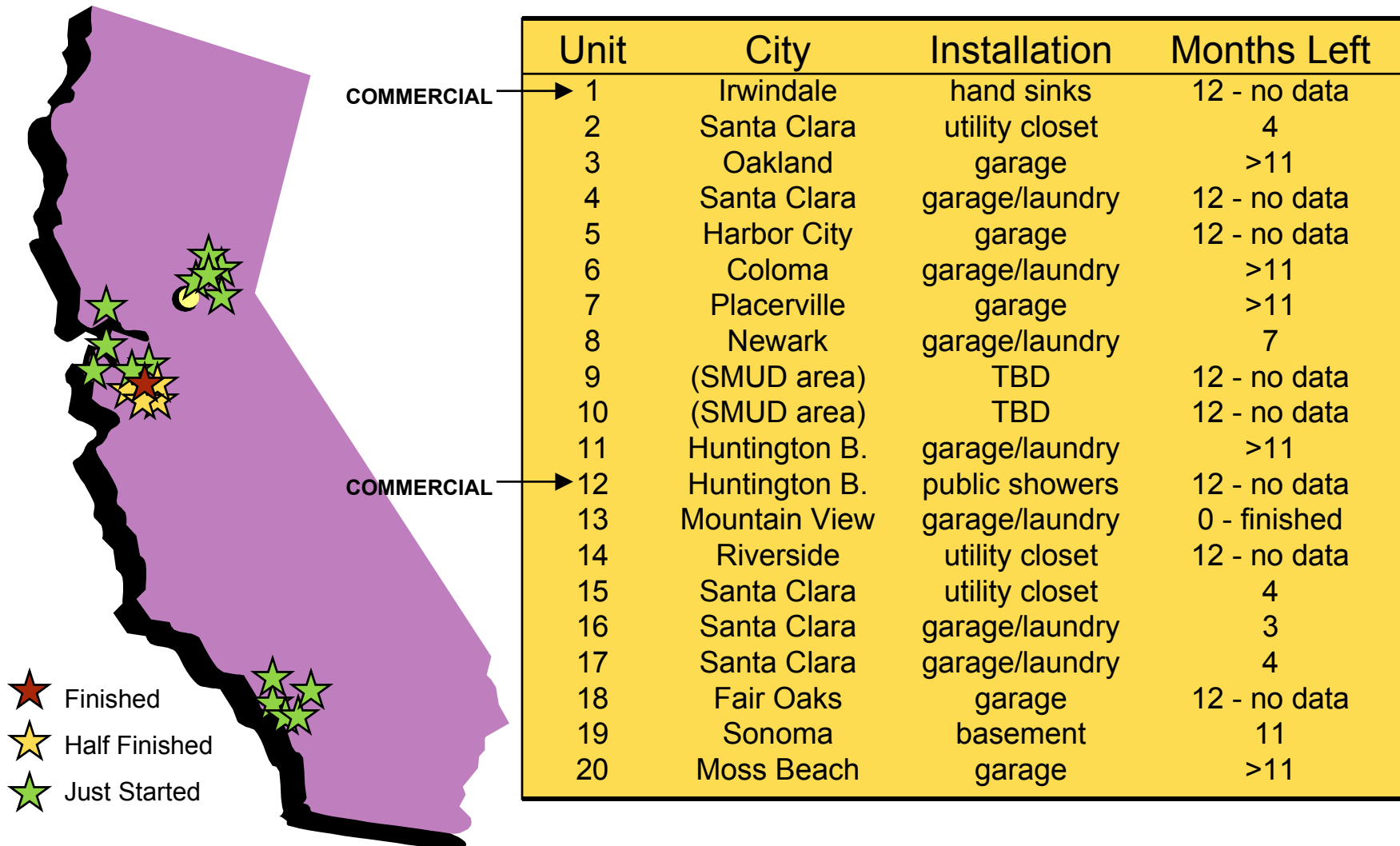
- Completed design refinements to bring the design into its third-generation, ready for production by ECR
- Conducted laboratory testing of the HPWH
- Worked with ORNL to complete durability testing
- Completed the Field Test Plan that details the approach and goals for the field tests
- Partnered with three California utilities to support the field tests:
 - City of Santa Clara/Silicon Valley Power (SVP)
 - Sacramento Municipal Utility District (SMUD)
 - Southern California Edison (SCE)

In total we will field-test at 18 residential and 2 commercial sites in California that span a range of climates, household sizes, installation locations, and water qualities.



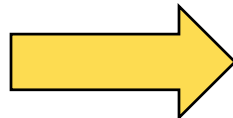
Two of the sites in the SMUD utility service area will be in the cool climate zone but the other three characteristics are not yet determined

One of the 20 field tests is finished, four others are more than half finished, and the rest have more than 6 months remaining.



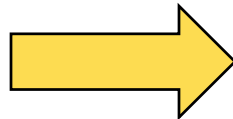
With a diameter of 22 inches, the HPWH generally fits well in tight spaces.

Garage Installation of Unit #16 in Santa Clara



With a height of 60 inches, the HPWH generally fits well in tight spaces.

Utility Closet Installation of Unit #2 in Santa Clara



We encountered no significant difficulties during the installations.

- A majority of the installation time and effort was spent bringing the installation into compliance with codes, which is equally time-consuming for conventional water heaters
- The additional weight (~50 lbs) and height (~13") of the HPWH did add time to utility closet installations because of the tight space constraints, but it had little effect on the time for less-constrained installations

Utility Closet Installation of Unit #15 in Santa Clara

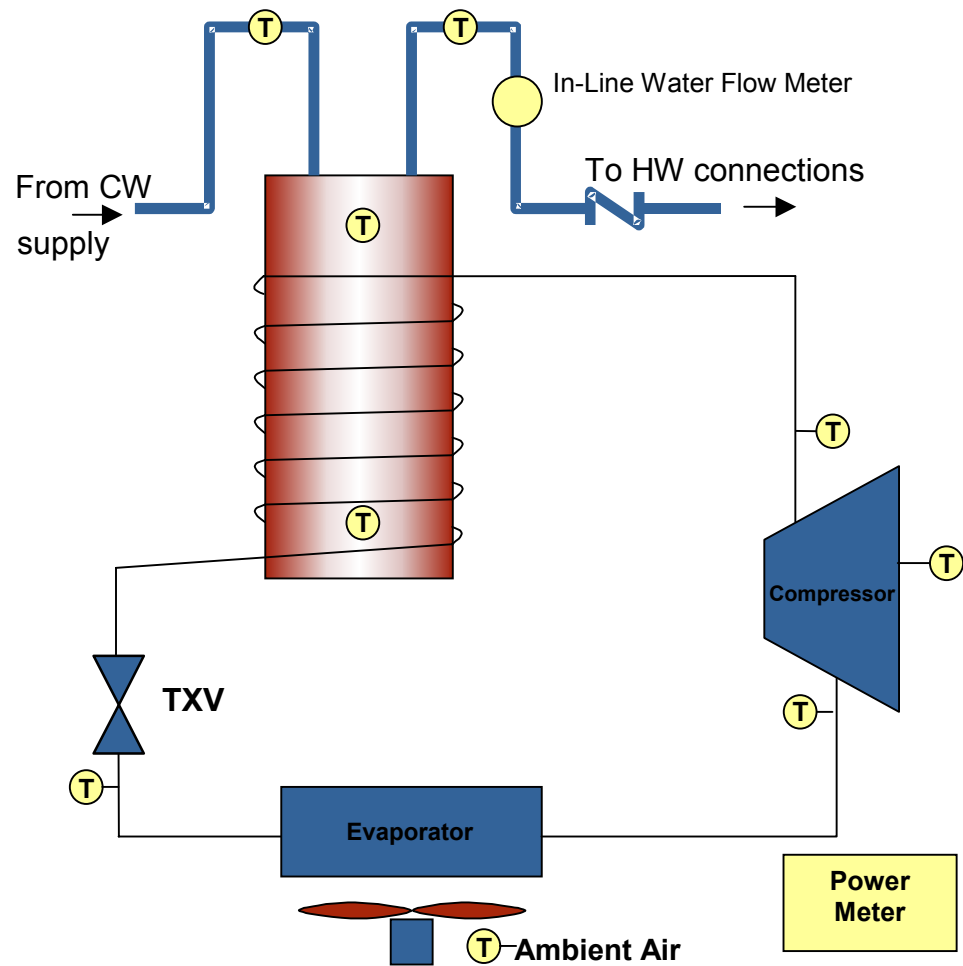


One field test unit was replaced and is under investigation, but no other significant maintenance issues have arisen.

- One unit was replaced because it was not meeting expected hot water capacity:
 - We have not yet determined the cause of the problem and ECR is investigating the unit that was replaced
 - During its replacement, a leak in the plumbing system was found that may suggest that the problem was not with the HPWH but with the existing plumbing system
- Several units were shutting off unexpectedly and required manual power reset. The control board manufacturer investigated and recommended disconnecting the board's ground wire. We did this on all the units and have not observed the problem since.

We are collecting detailed data from each field test unit by remotely interfacing with the data collection and instrumentation systems.

- Data are collected every minute and retrieved daily:
 - HP component temperatures
 - Water temperatures
 - Water flow rates
 - Electric power consumption
- TIAX developed in-house software to remotely collect and analyze the data from each unit.
- Each test runs for one year.

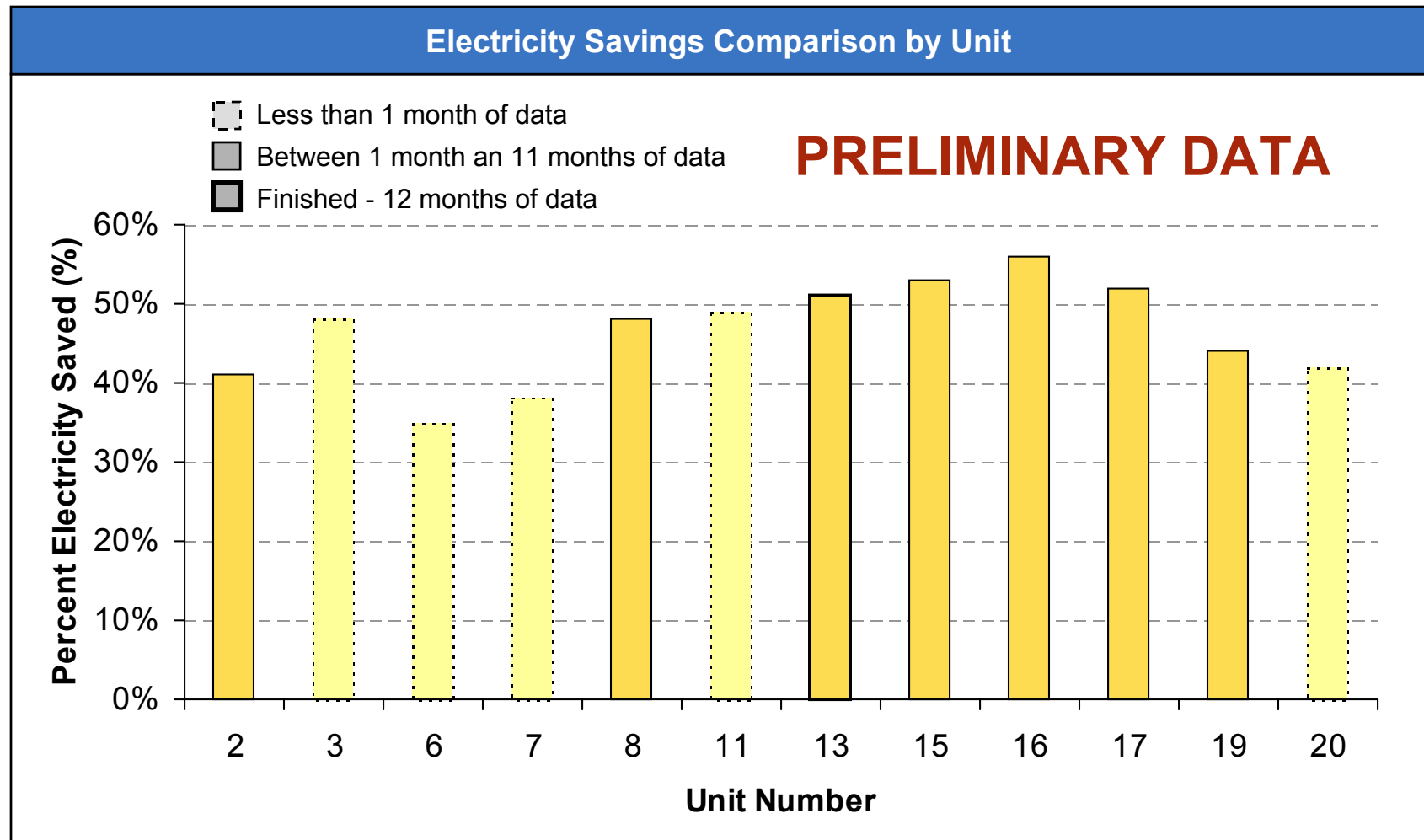


We are simulating the performance of a conventional electric water heater at each site with a simple performance model.

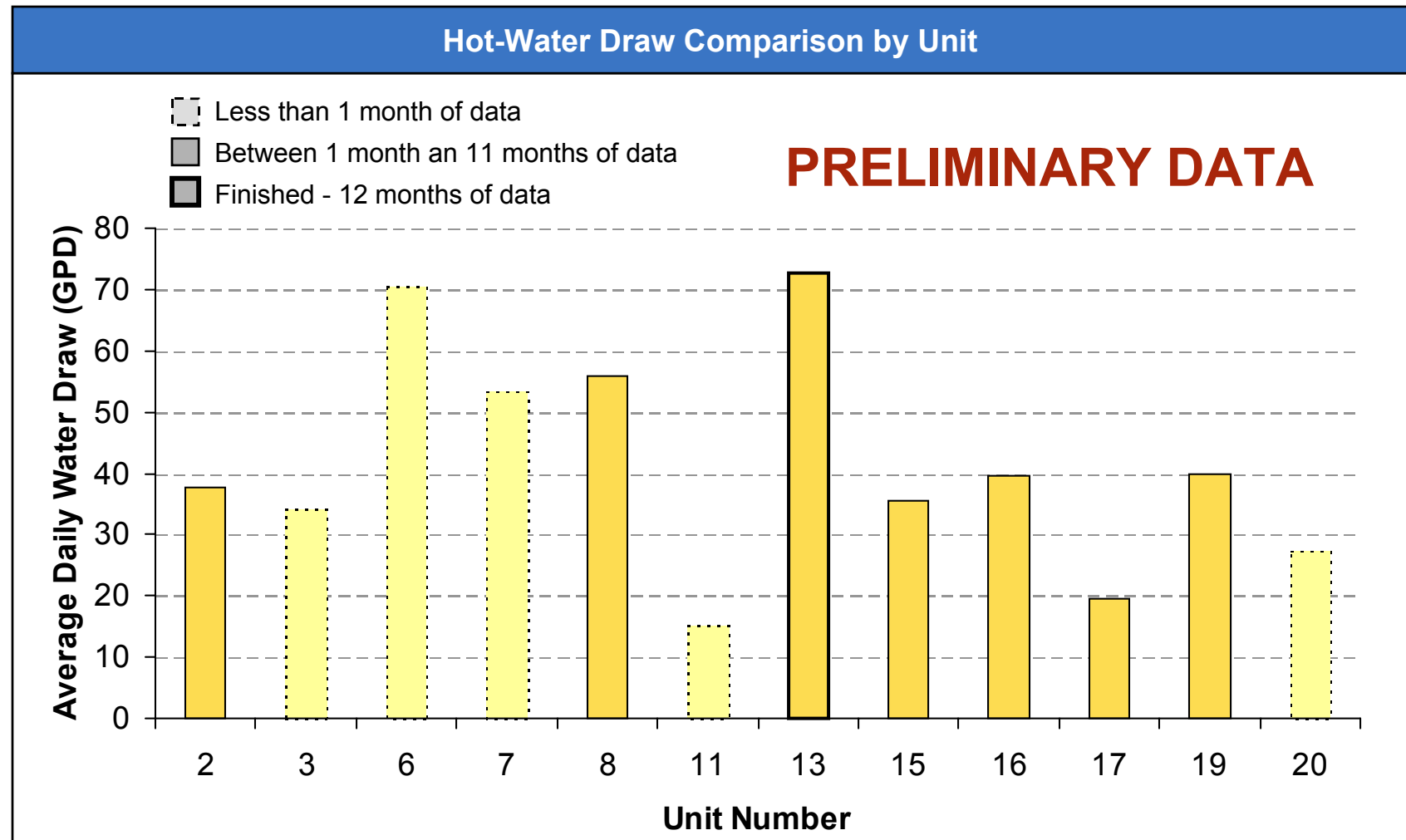
- The model is used to calculate energy savings and conventional hot-water deficits
- It performs an energy balance of the system at each minute based on water draw and temperature data collected from each HPWH test
- It estimates the bulk temperatures of the upper and lower portions of the 50-gallon tank
- The element capacity is nominally sized at 4500W but accounts for differences in actual site voltage
- Stand-by losses are calculated using a fixed UA value for the tank
- Buoyancy and stratification effects are considered

This simple model is a preliminary method for simulating conventional electric water heaters and is subject to change.

The simulated electricity savings range between 41% and 57% for field tests that have been running for at least a month.



Energy savings are consistently high over a wide range of water consumption (15 to 71 GPD).

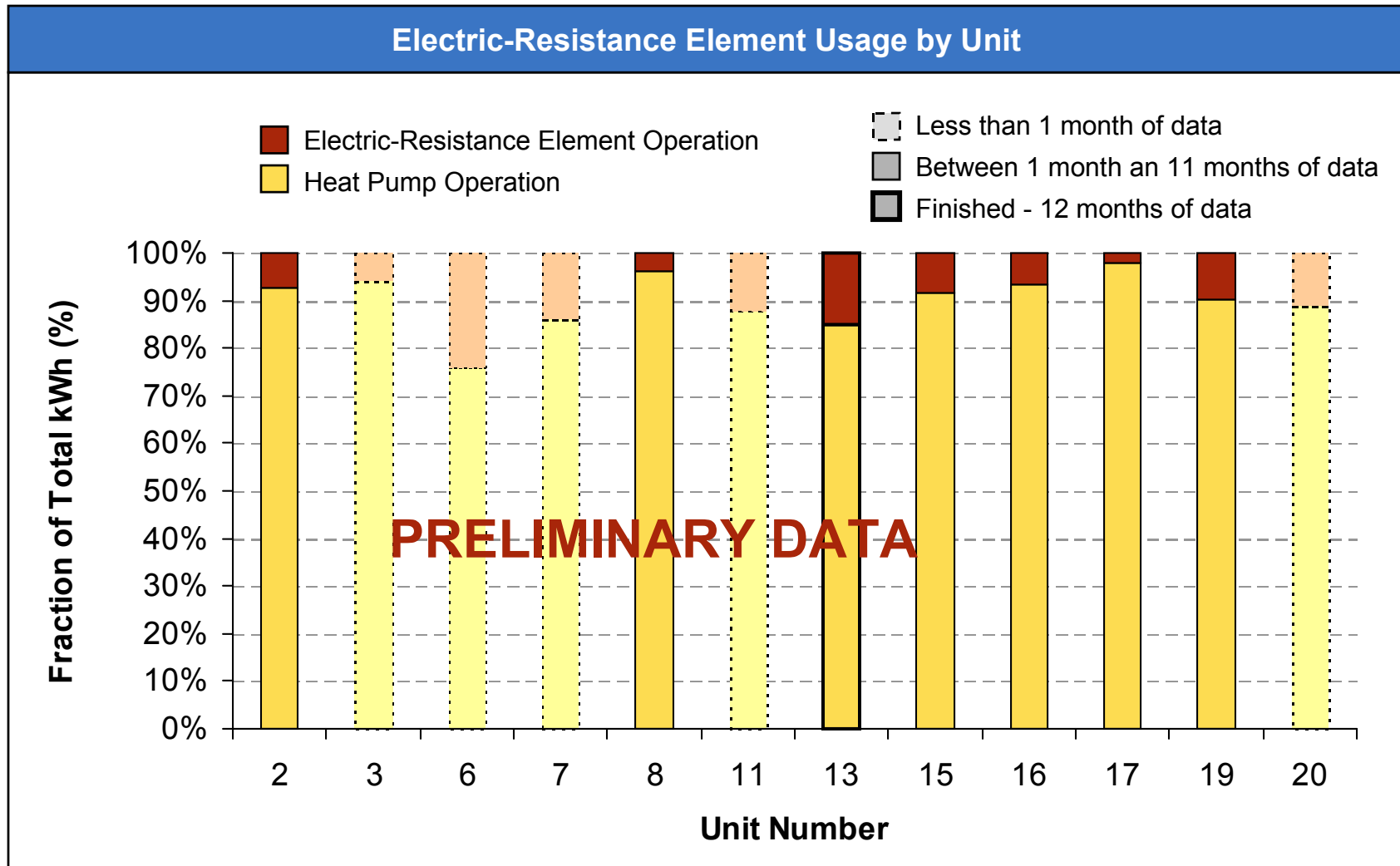


While average water draw does not seem to limit relative energy savings, other variables may have a more substantial impact.

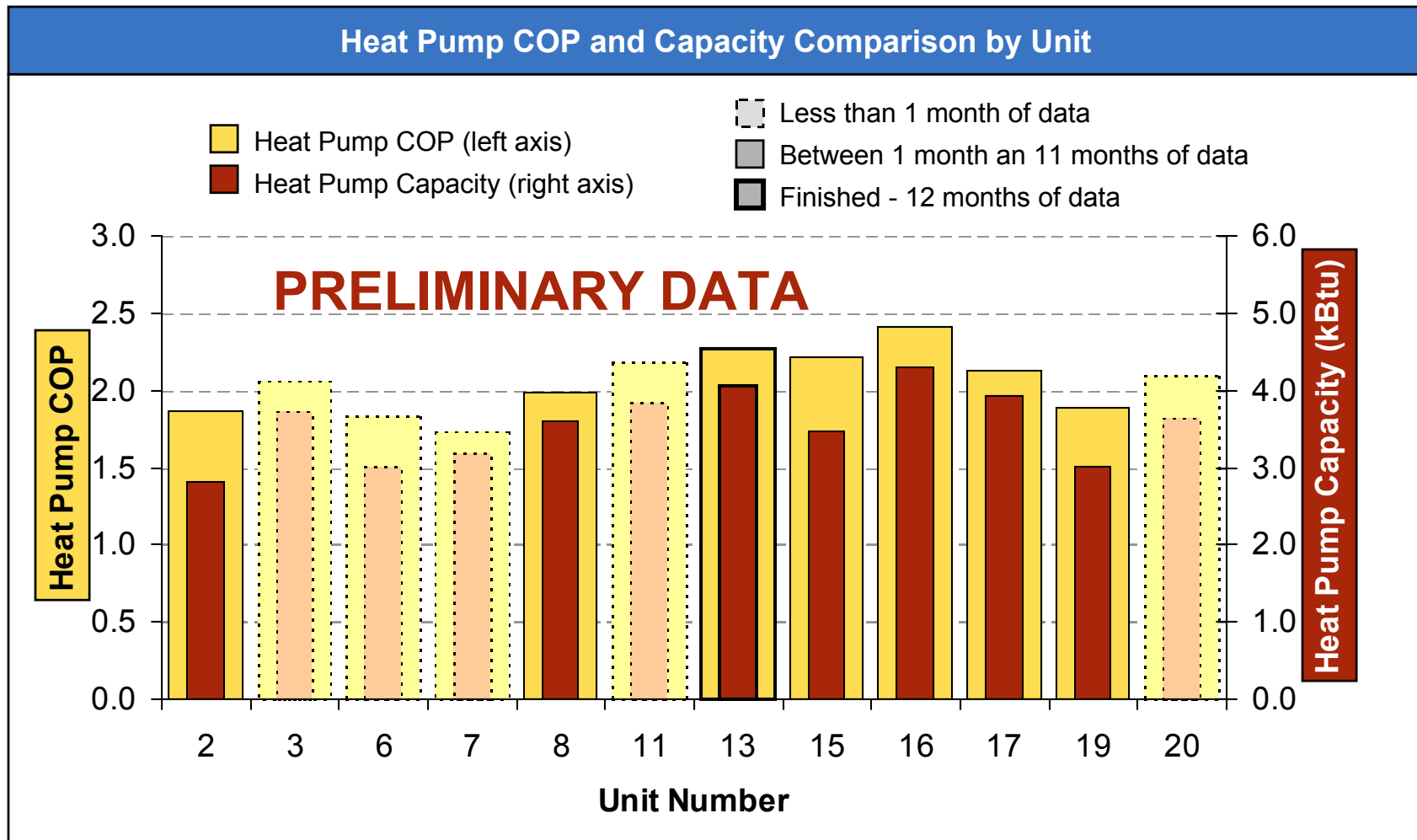
- Ambient air temperature impacts heat pump efficiency:
 - For example, Units 6 and 7 have been running for less than a month in a cold climate
- Spikes in water draw profiles will trigger the use of back-up resistance heating elements:
 - For example, Units 6 and 13 have similar average water draw, but Unit 6 has higher spikes
- Operating a HPWH in a confined space leads to cooler air temperatures and hence impacts efficiency

We will investigate these impacts as we gather more data.

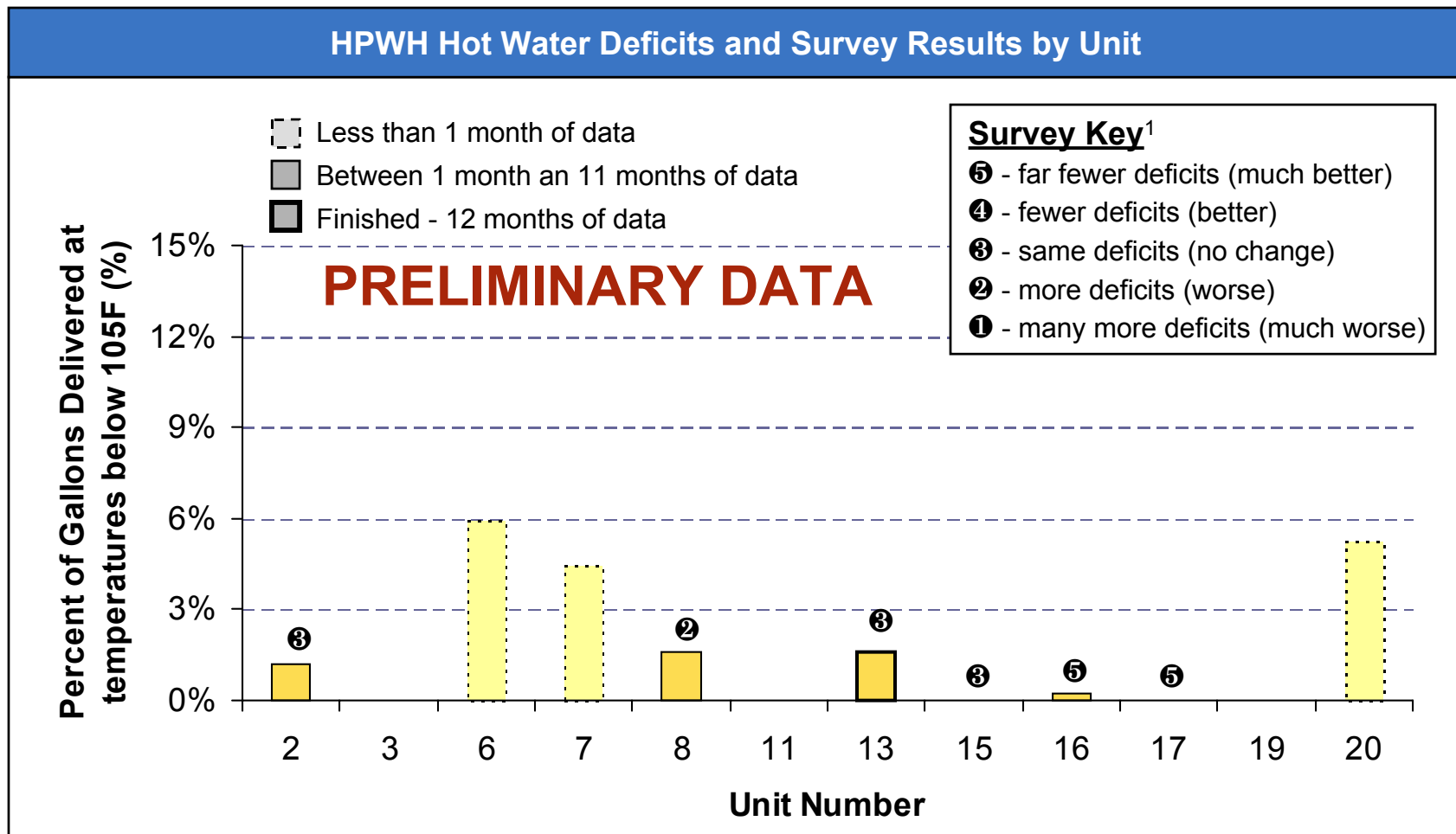
For units operating more than a month, the heat pump provided over 85% of the water heating.



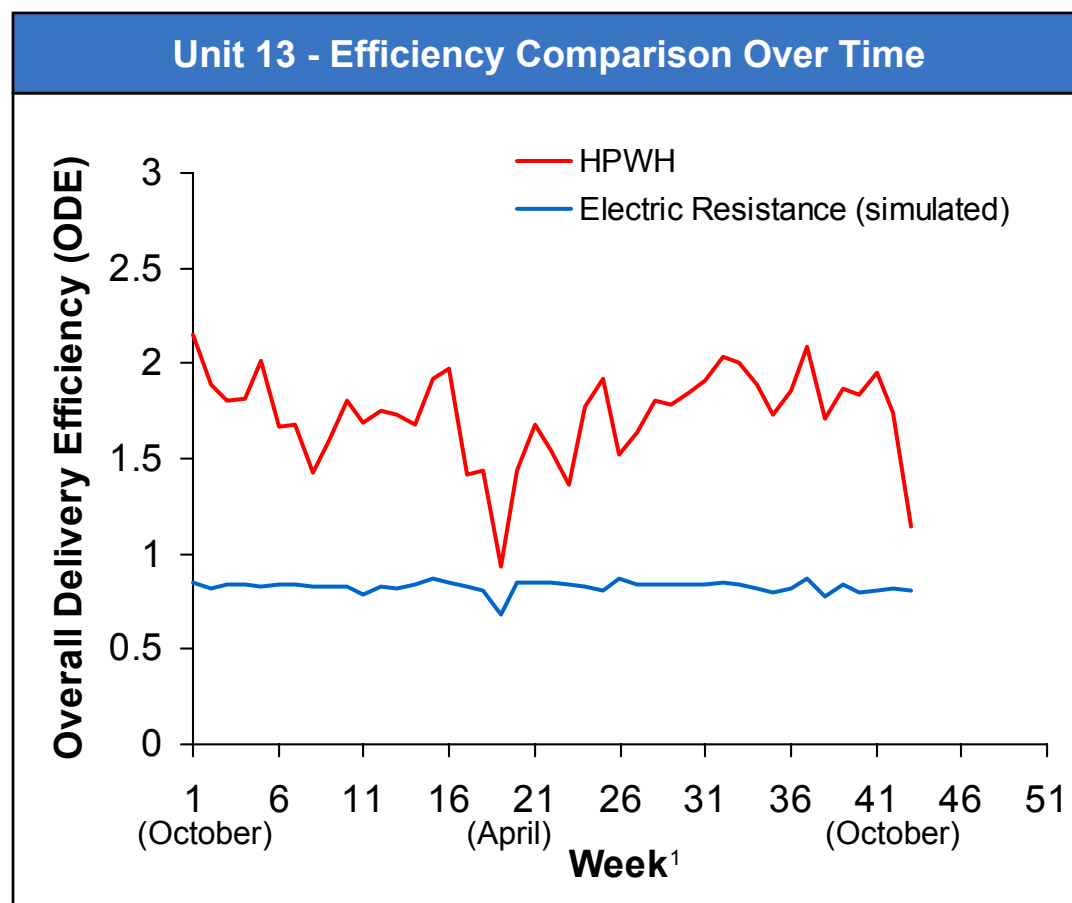
Variations in operating conditions likely explain the minor fluctuations in heat-pump COPs and capacities, but more data are needed.



We measured hot-water deficits (<105°F) in several units, but early survey results show that deficits are generally perceived to be no worse than the old electric-resistance water heaters, and in some cases even better.



The efficiency of a HPWH (data for Unit #13 is shown) varies over time considerably more than it does for a conventional electric water heater.

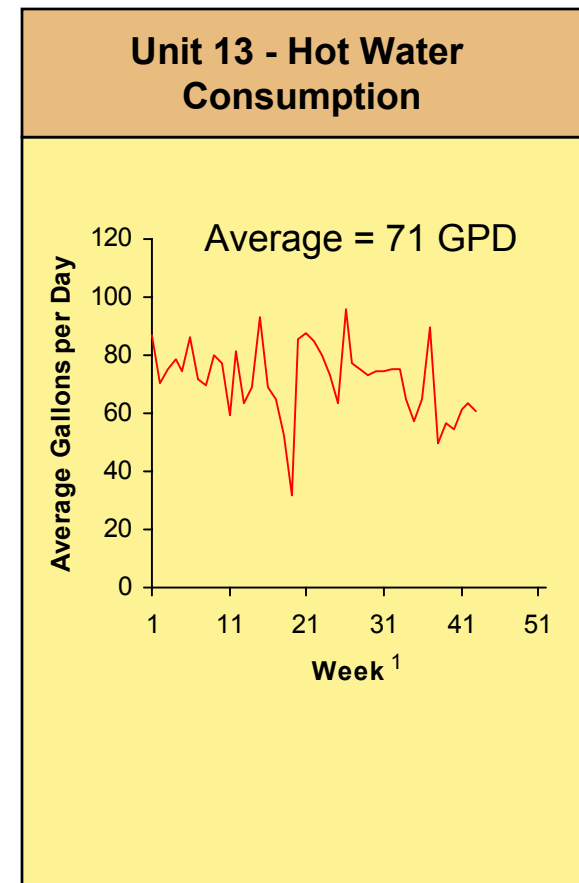
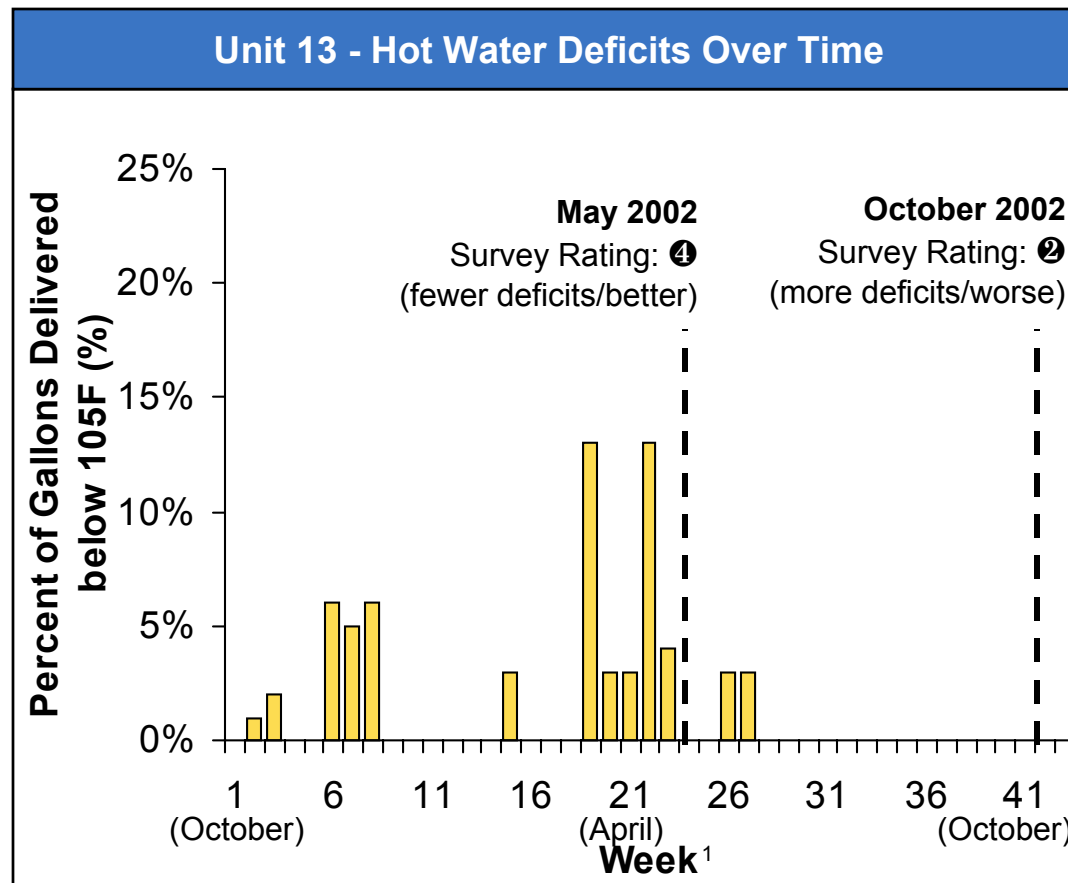


- The test unit (#13) is installed in the garage of a 4-person home in Mountain View, California (near Santa Clara) with a moderate climate and moderate water quality
- The average HPWH ODE² (overall delivery efficiency) for unit #13 was 1.7
- The average electric resistance ODE² was 0.8 based on simulations

¹ Weeks are not continuous because of data collection gaps (43 weeks of data covers 12 full months)

² Overall delivery efficiency (ODE) is defined as the total energy delivered divided by the electric energy consumed

For Unit #13, the survey results show that perceived water deficits do not correlate with measured deficits.



¹ Weeks are not continuous because of data collection gaps (43 weeks of data covers 12 full months)

Based on our initial field test results, we anticipate that our program will mirror the encouraging success of the ORNL field test program.

- Our initial results are consistent with the ORNL field tests
- Large relative electricity savings (40% to 50%) are possible even over a large range of average daily water draws (20 to 70 GPD)
- Other variables such as peak water draw, climate, and installation location may have more noticeable impacts on electricity savings, but more data are needed to draw firm conclusions

We will complete the California field test in 2003, and publish results in early 2004.

- Fabrication Report
- Field Test Report (including participant survey results)
- Lessons Learned & Information Dissemination Plan
- Final Report